Fermilab

νSTORM

Neutrino fluxes at nuSTORM

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MAP Winter Meeting
SLAC
6th December 2014

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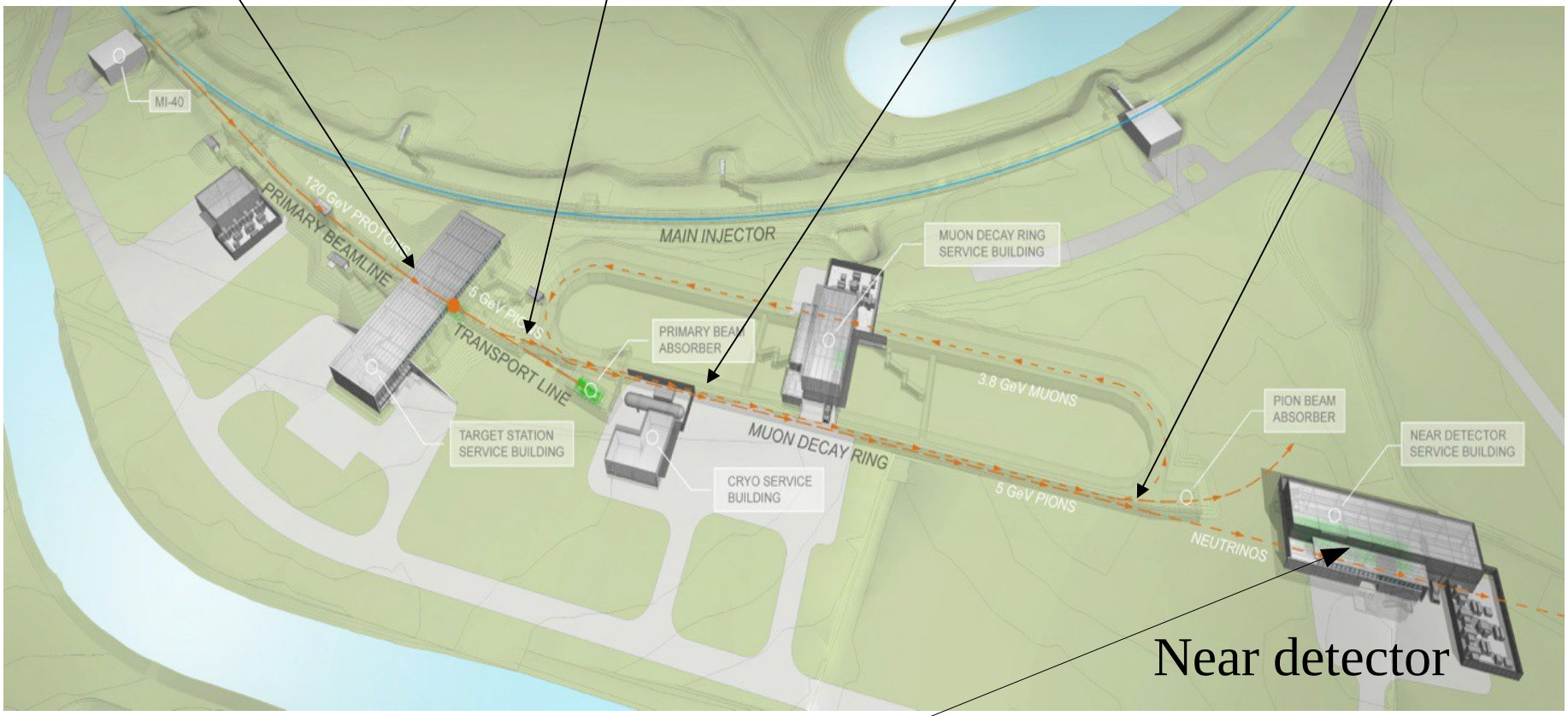
Protons on Target Horn collection (MARS)

Pion transport - G4Beamline

Pion injection – G4Beamline + sampling

Muons sampled at the end of decay straight



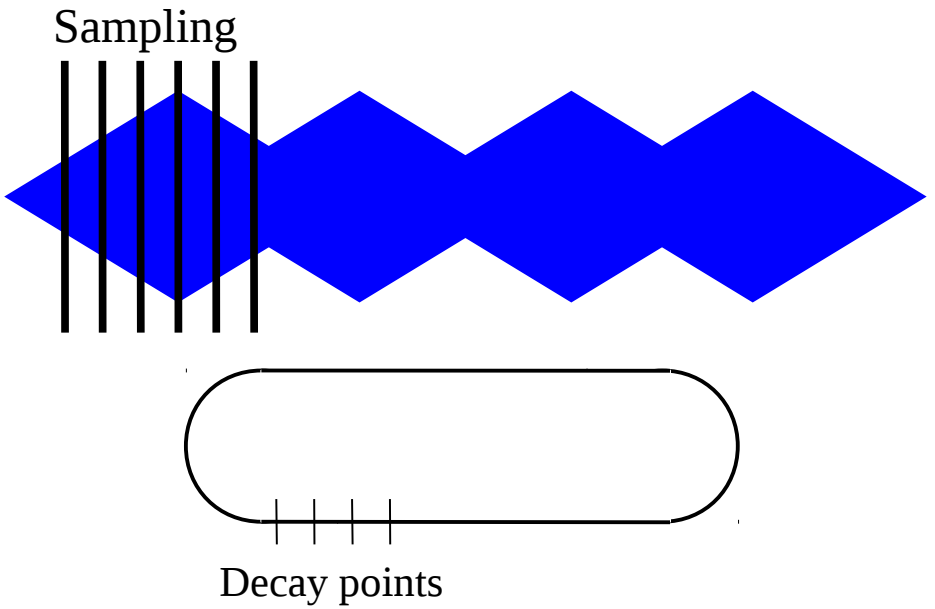
Near detector

Samples of pions (kaons and decay products) used to calculate flux at arbitrary angles and baselines

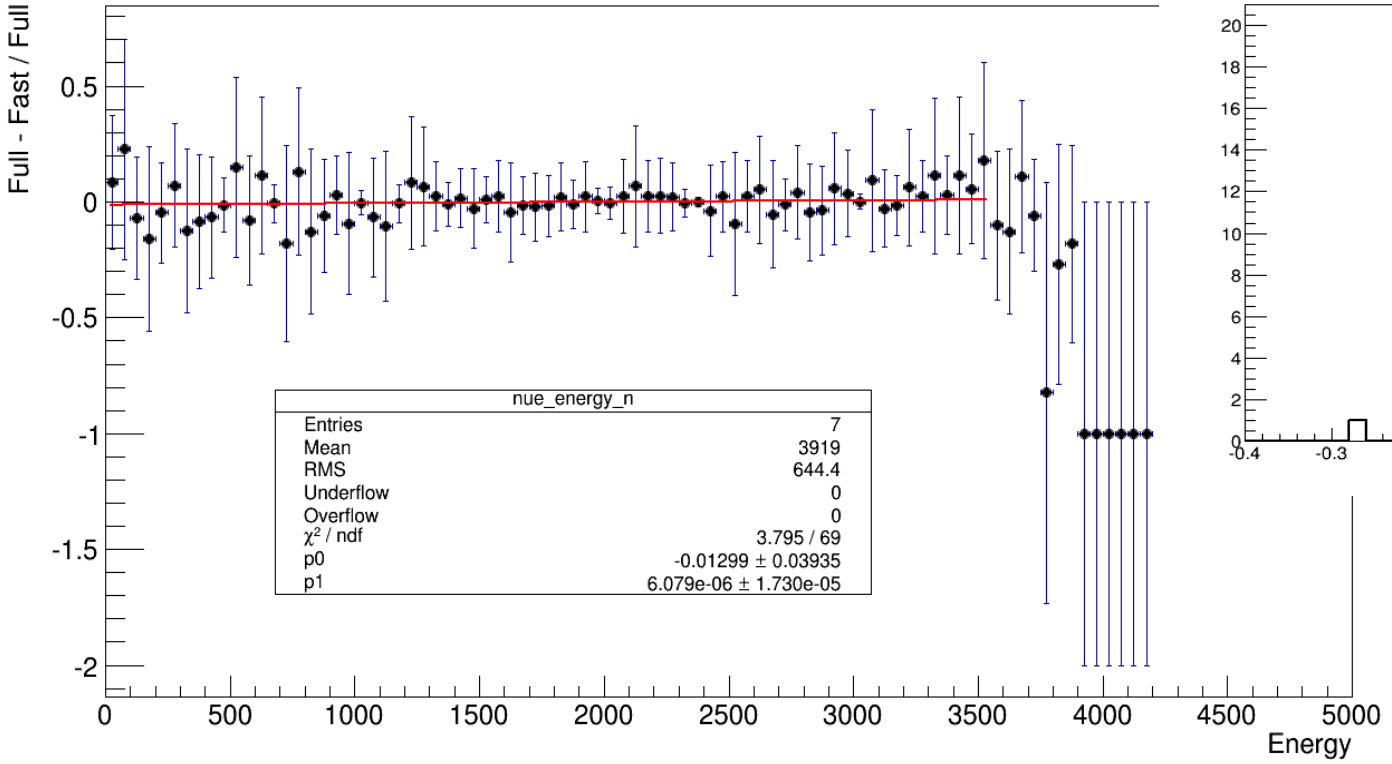
Decays in G4Beamline sampled at near detector

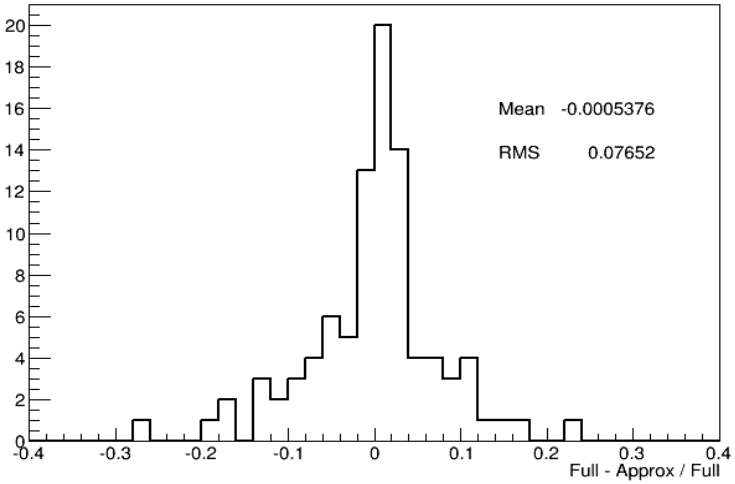
Beam tracking approximation

- Pions, kaons + decay product samples – calculate flux
- Muons tracked along straight – calculate flux
- Pions samples decayed at locations – simulate flux
- Muon samples decayed at locations – simulate flux



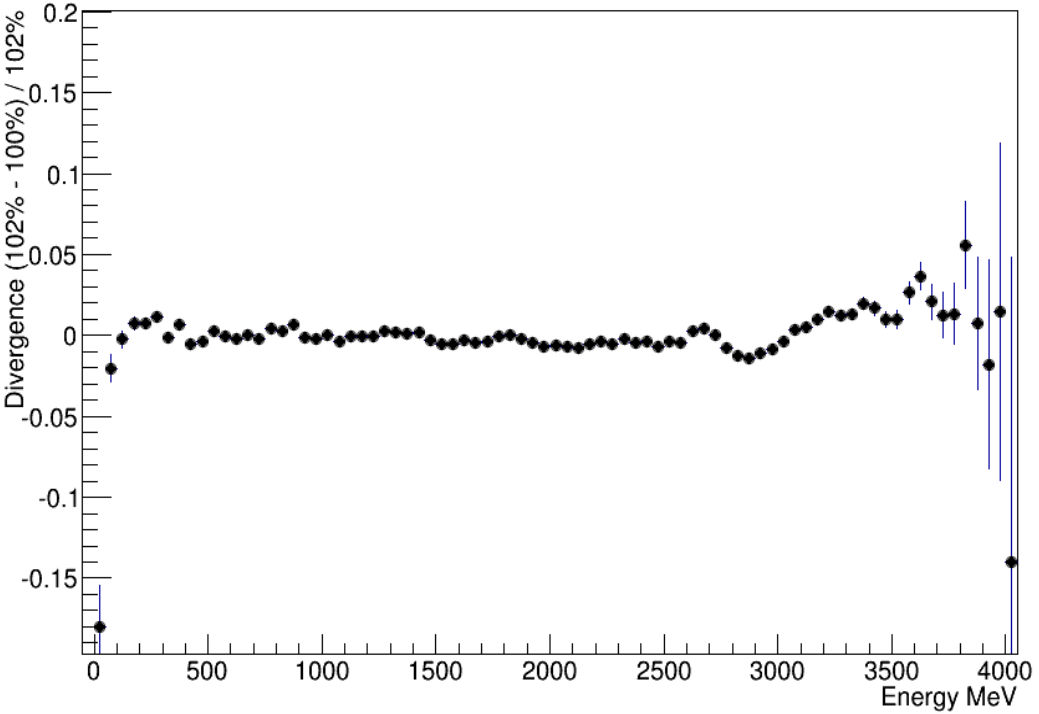
Approximation accuracy

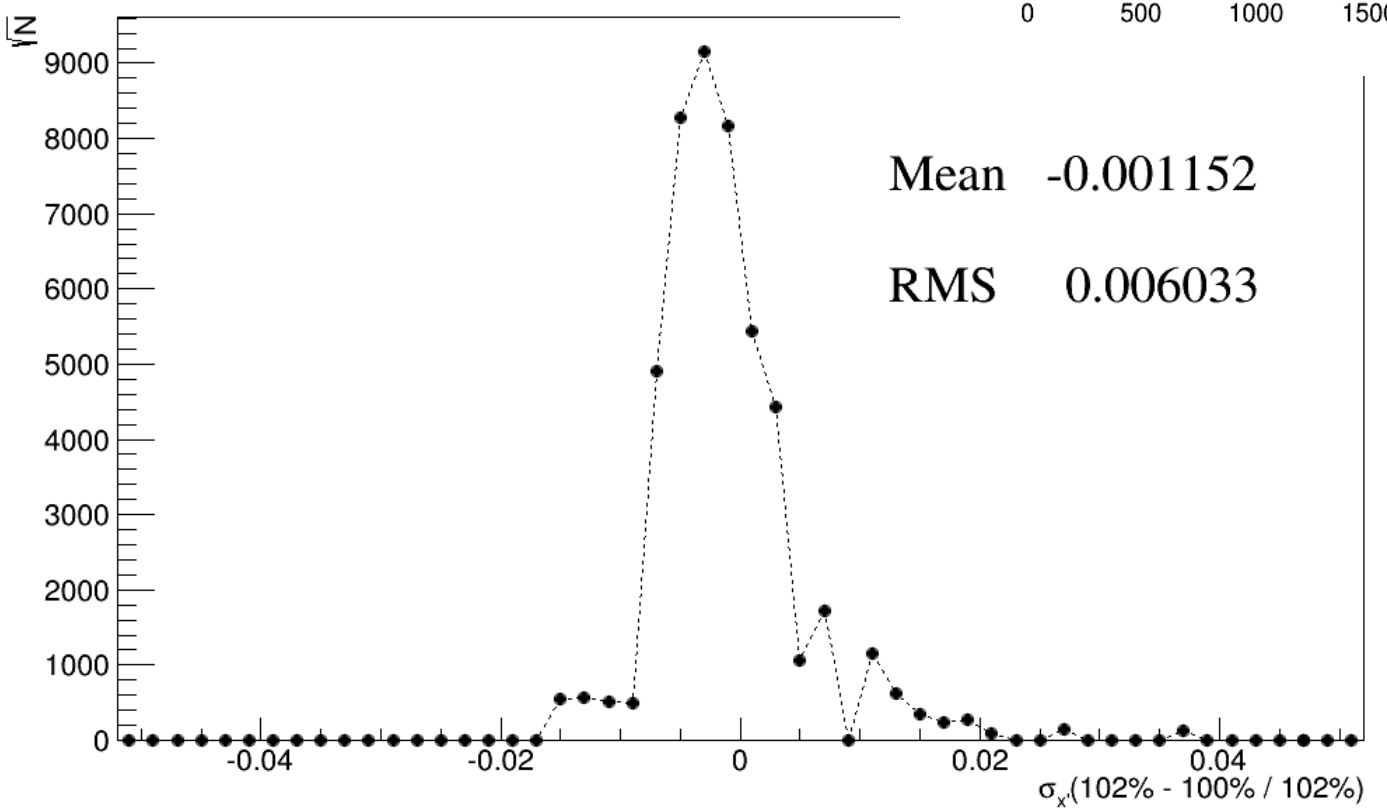




Divergence errors

- Muon beam re-simulated with a divergence inflated by 2%
- Resulting neutrino flux compared to nominal beam
- Less than 1% difference bin-to-bin

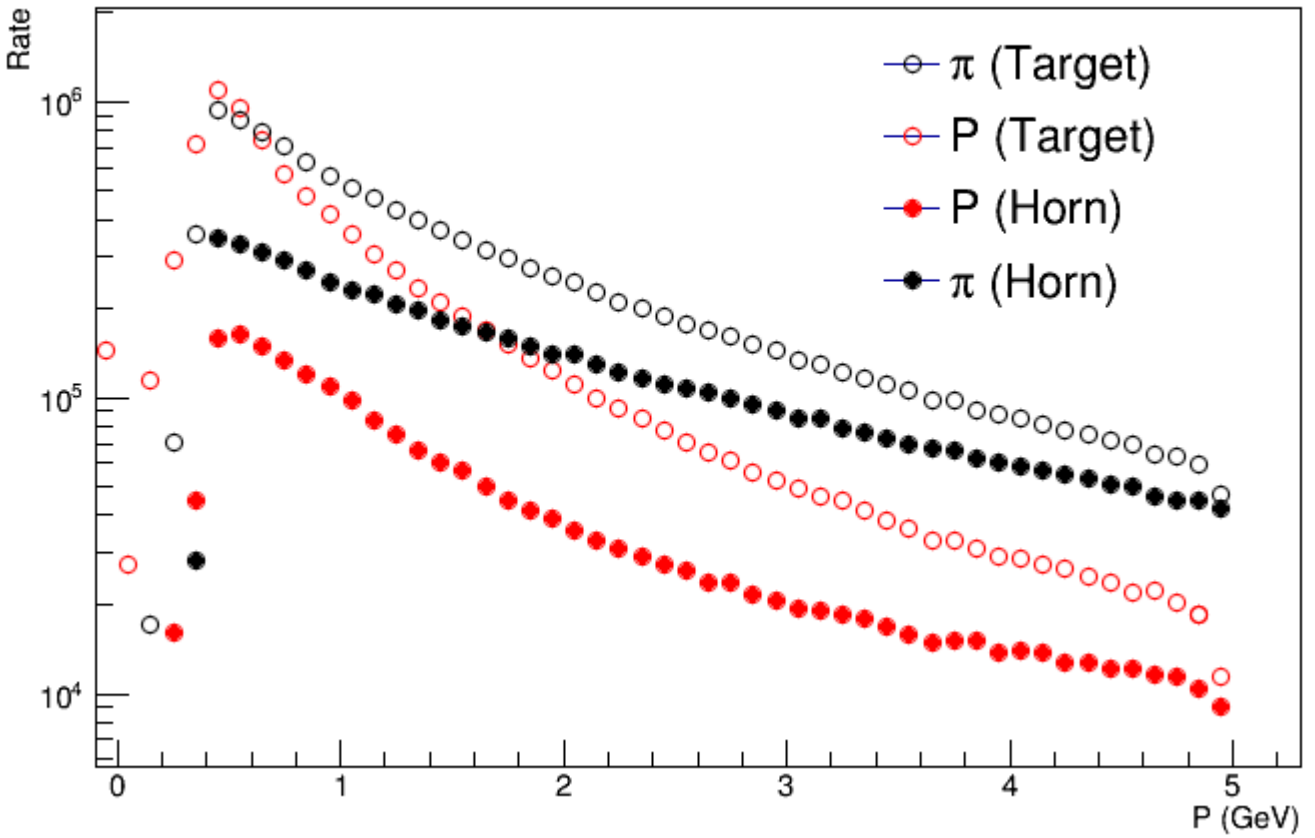




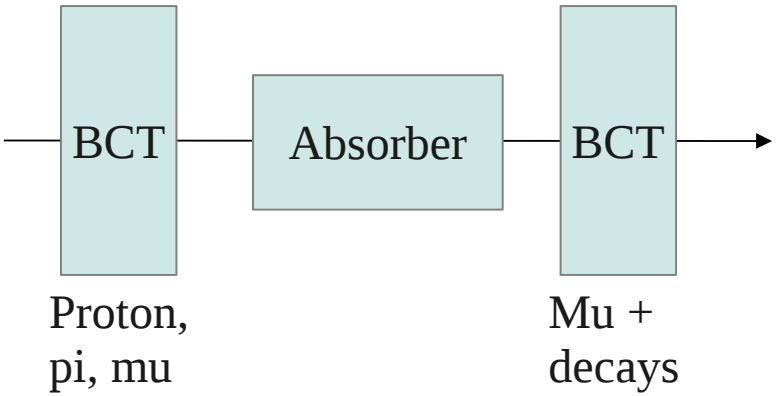
Source	Error
Intensity	0.1%
Divergence	0.6% with 2% measurement
Energy spread	0.1%

Primary proton contamination

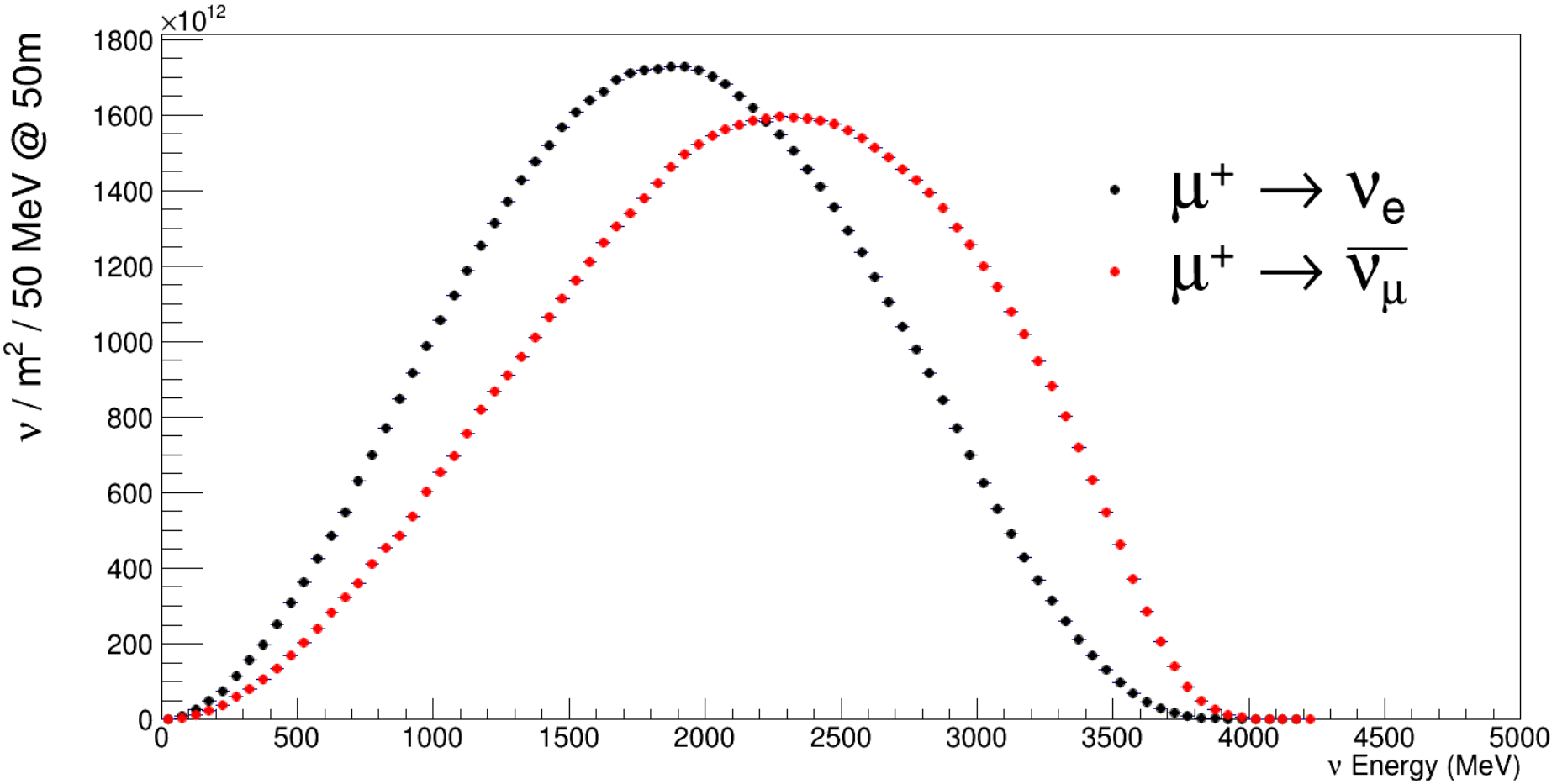
- BCTs quoted as measuring intensity to 0.1%
- What about proton contamination?
- What about large beam size?
- What about halo hitting BCT?
- What about pion beam v. Muon beam



- According to vendor, size of beam is not an issue
- Beam collisions with the BCT would need experiment
- Pion contamination could be measured during destructive commissioning phase

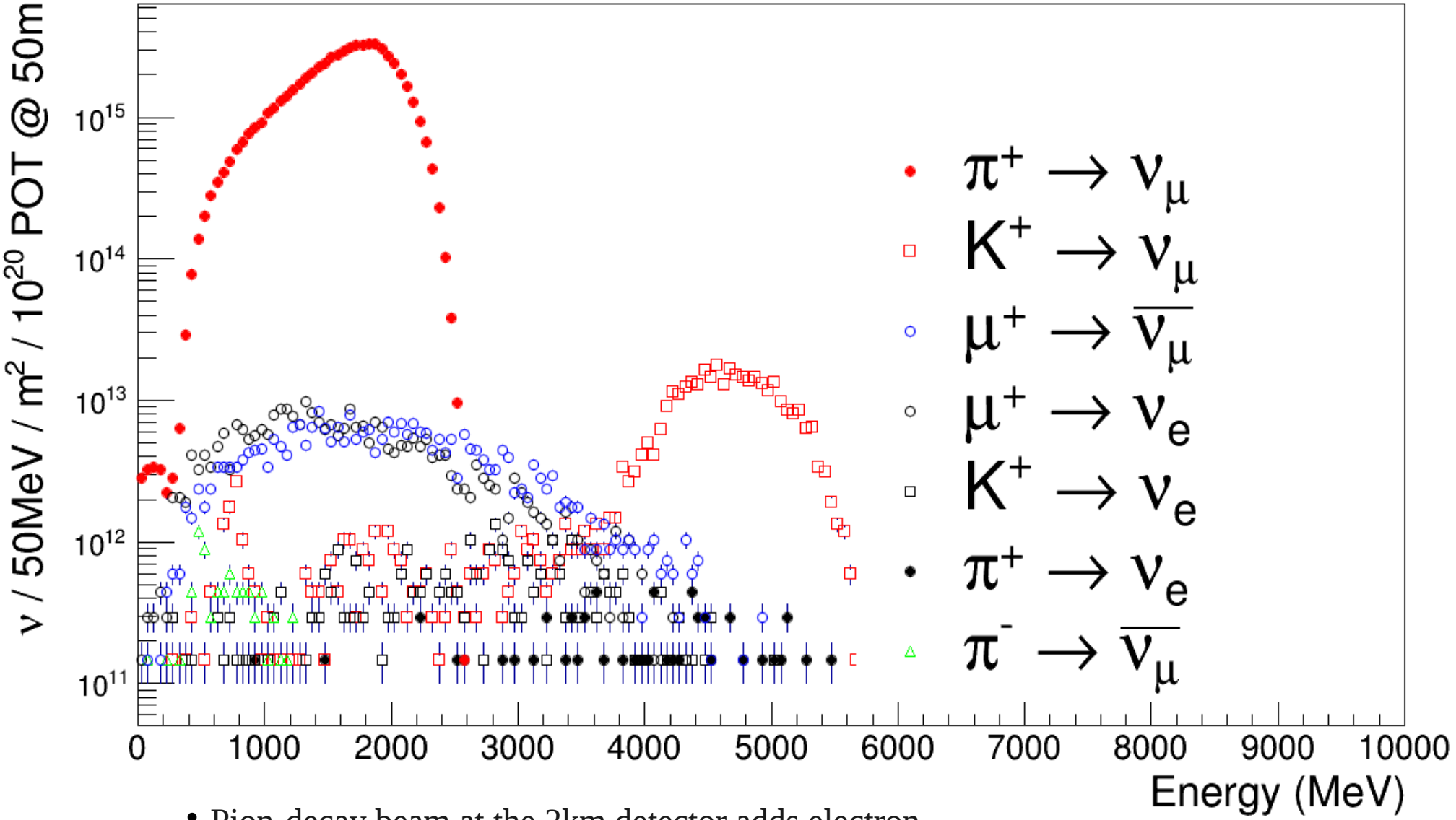


Flux from muon decay at 50m



- Muon beam tracked through decay straight using G4Beamline
- Distribution used to generate decays and neutrinos sampled at 50m near detector site
- Likely amplification with horn optimisation

Near (50 m) detector flux from pion decay



- Pion-decay beam at the 2km detector adds electron appearance channel and increased options for NC disappearance

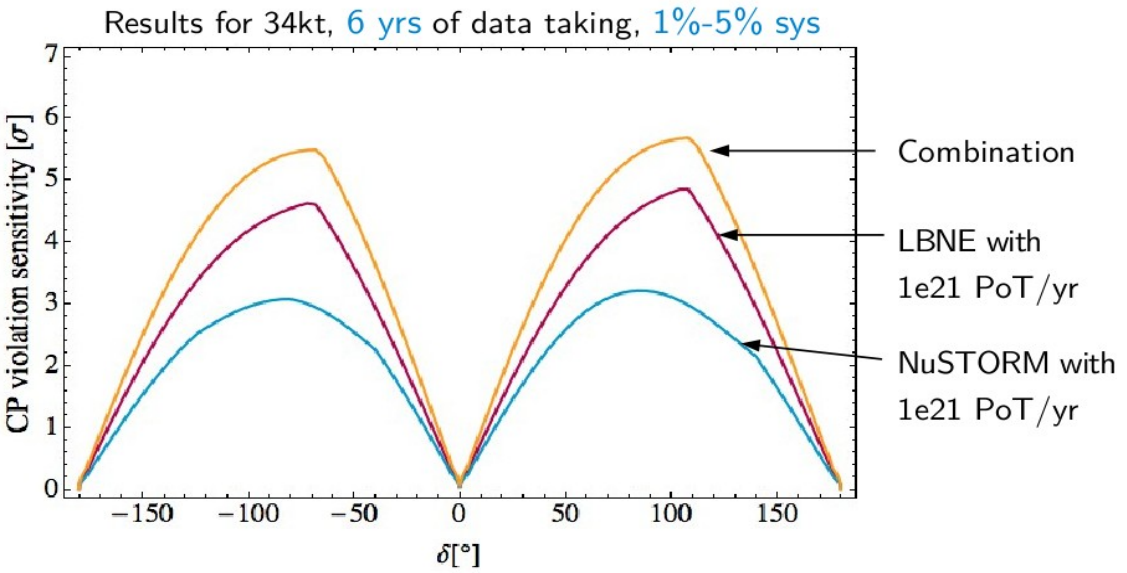
μ+ Stored		**μ- Stored**	
Channel	*Events*	*Channel*	*Events*
ν_μNC	1,174,710	ν_eNC	1,002,240
ν_eNC	1,817,810	ν_μNC	2,074,930
ν_μCC	3,030,510	ν_eCC	2,519,840
ν_eCC	5,188,050	ν_μCC	6,060,580
π+		**π-**	
ν_μNC	14,384,192	ν_μNC	6,986,343
ν_μCC	41,053,300	ν_μCC	19,939,704

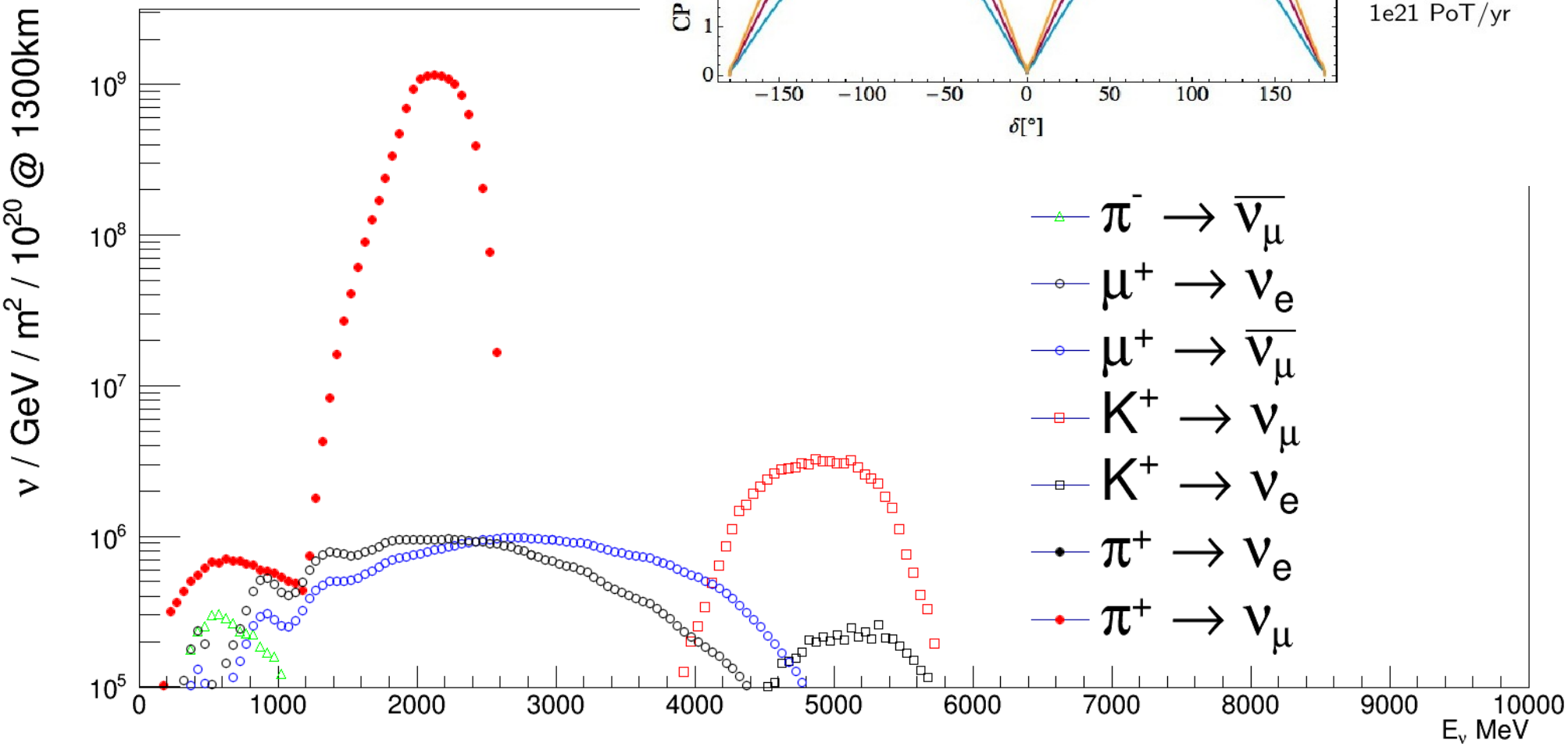
- Event rates at 50m per 100T for full exposure of 10^{21} POT

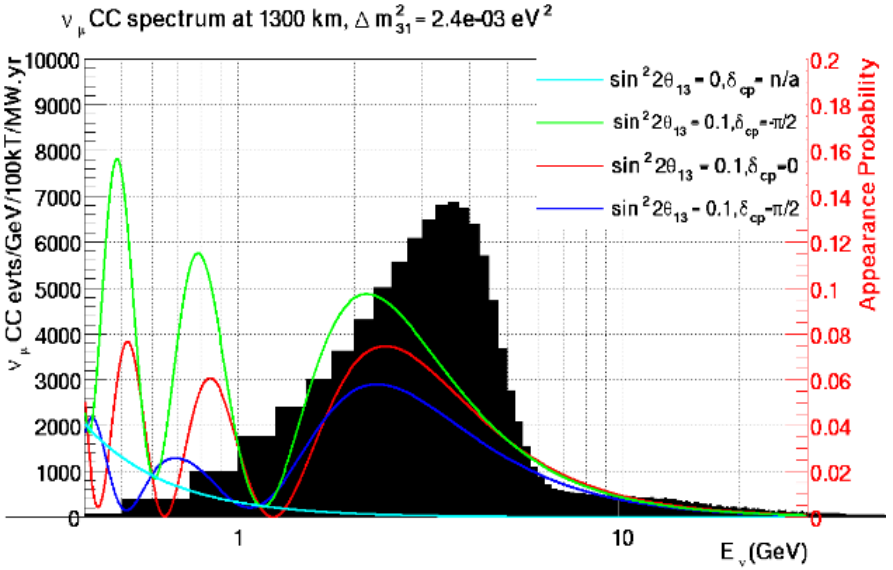
Very Far (1300 km) detector flux from pion decay

- nuSTORM long-baseline contribution to CP only – does not include contribution to cross-section systematic

CP violation sensitivity



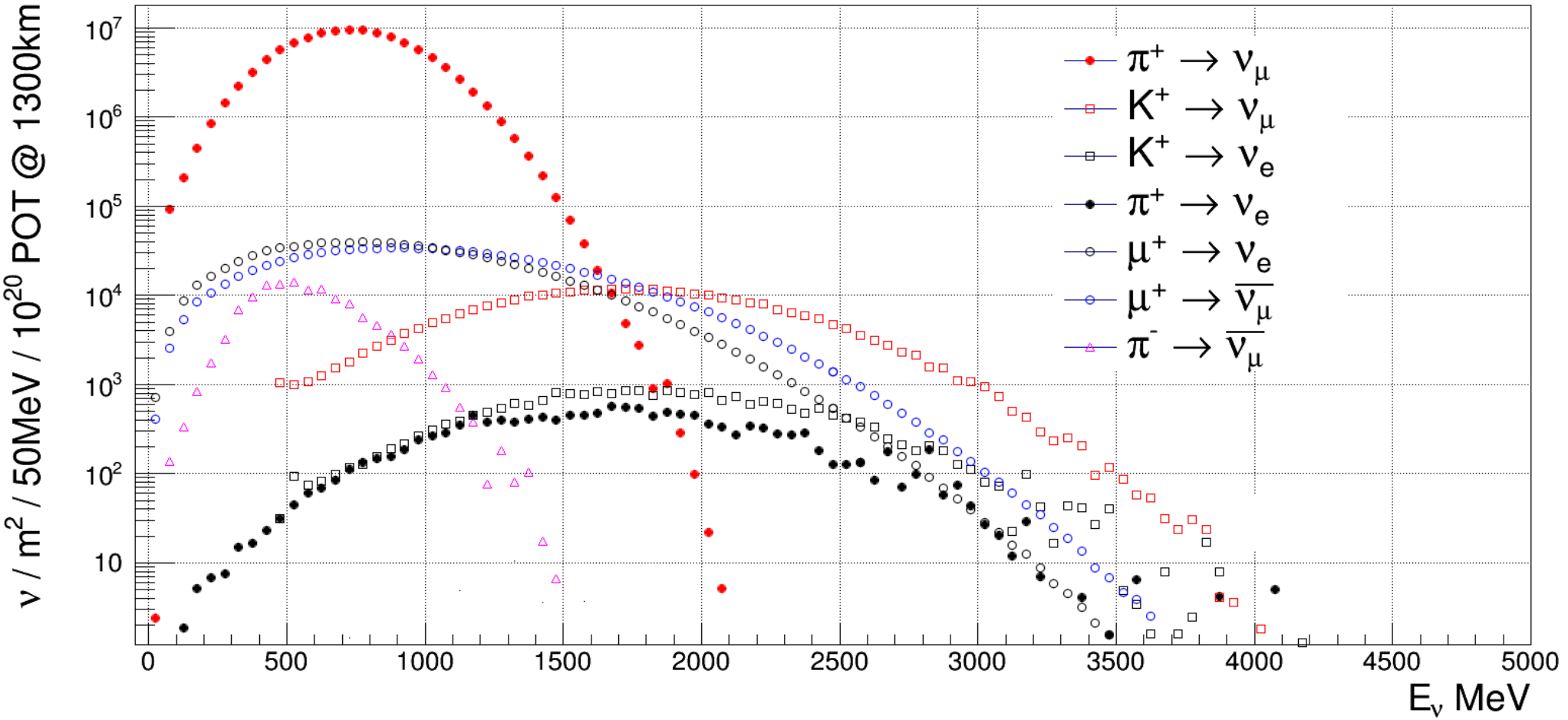




Very Far (1300 km) detector flux from pion decay – 2nd oscillation maximum

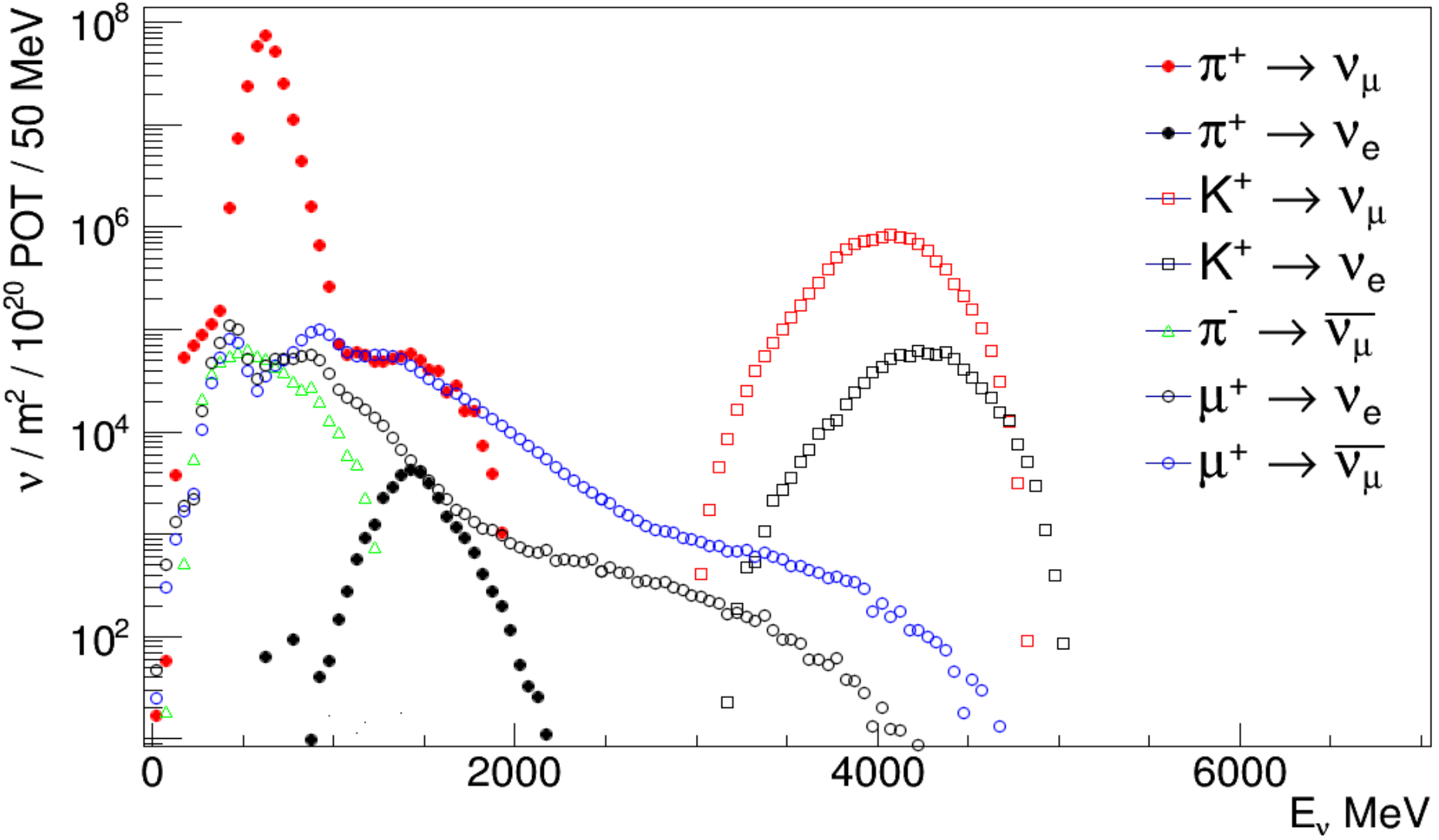
Still not an optimized pion beam, increased rate with momentum acceptance and move to pion only beam

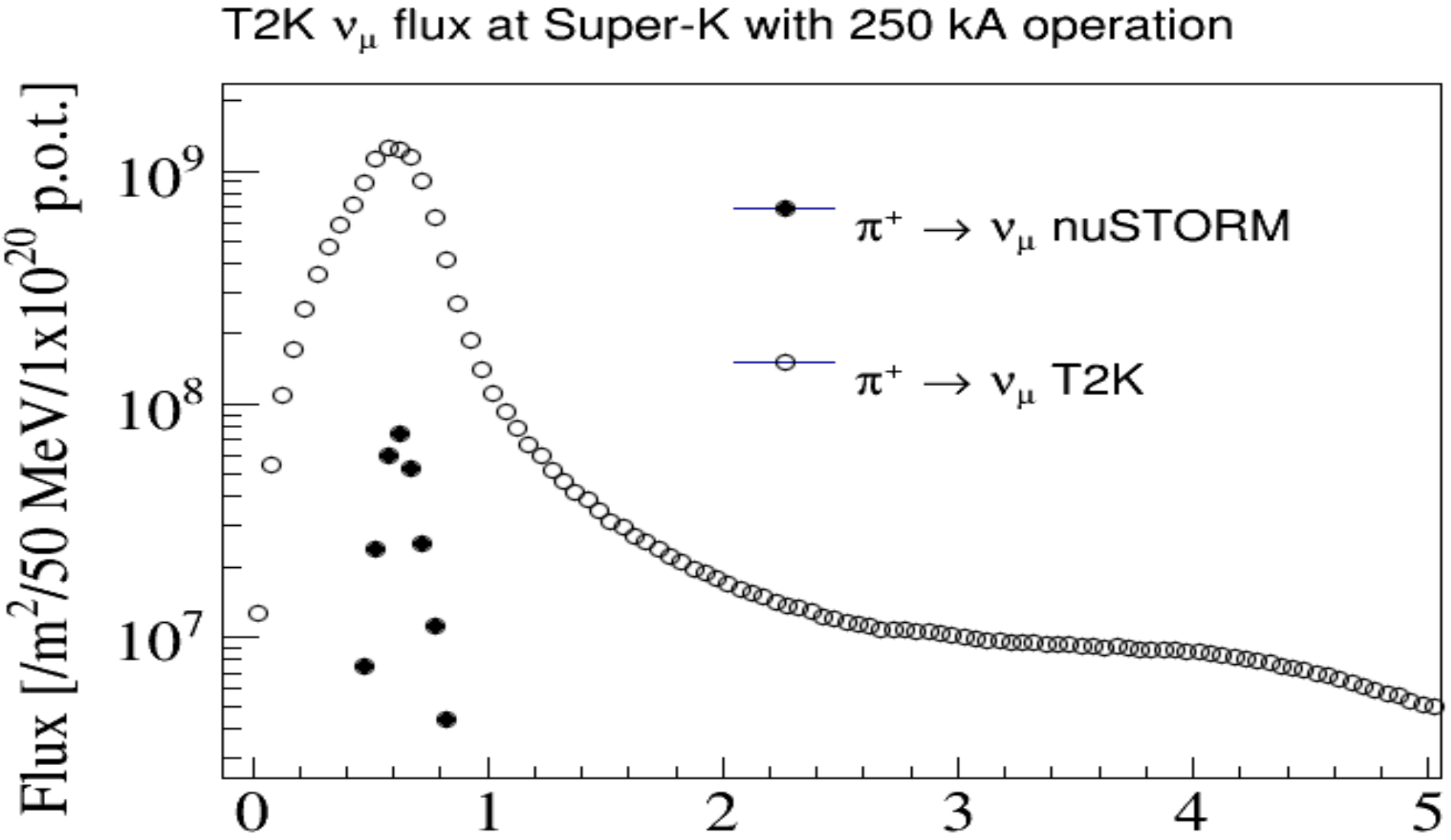
P_π = 1.3 GeV

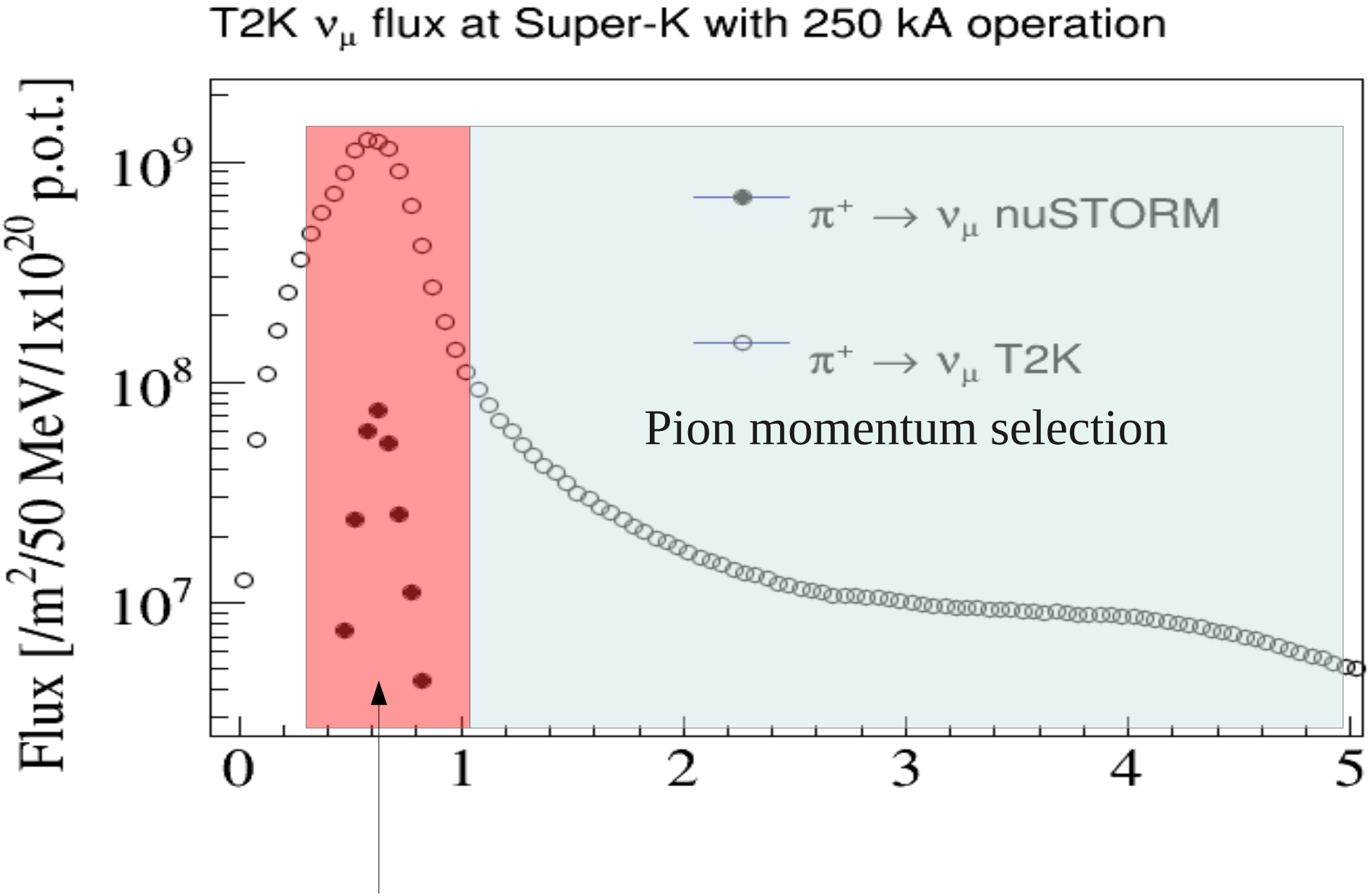


nuSTORM + JPARC

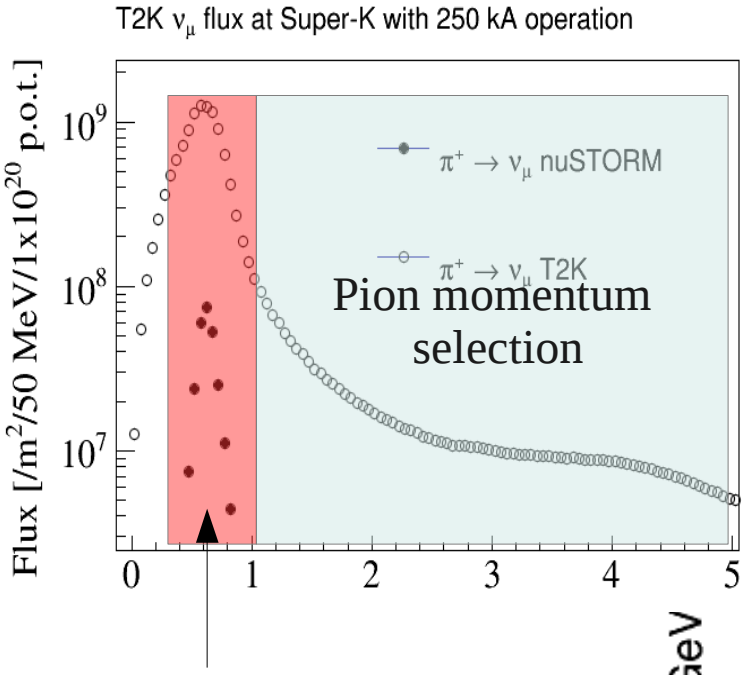
- Inquiry about nuSTORM flux at a T2HK near detector site – 2km 2.5degress off-axis – consider also full T2K baseline
- Target and horn re-simulated with 30GeV proton beam – no appreciable change in pion phase space but expected 4x reduction in pion production
- Re-scaling of neutrino flux visible at 295km 2.5degrees off-axis




T2K ν_μ flux at Super-K with 250 kA operation
Flux [/m^2/50 MeV/1x10^{20} p.o.t.]
10^9
10^8
10^7
0
1
2
3
4
5
$\pi^+ \rightarrow \nu_\mu$ nuSTORM
$\pi^+ \rightarrow \nu_\mu$ T2K



Factor 10 deficiency in flux in energy band of interest

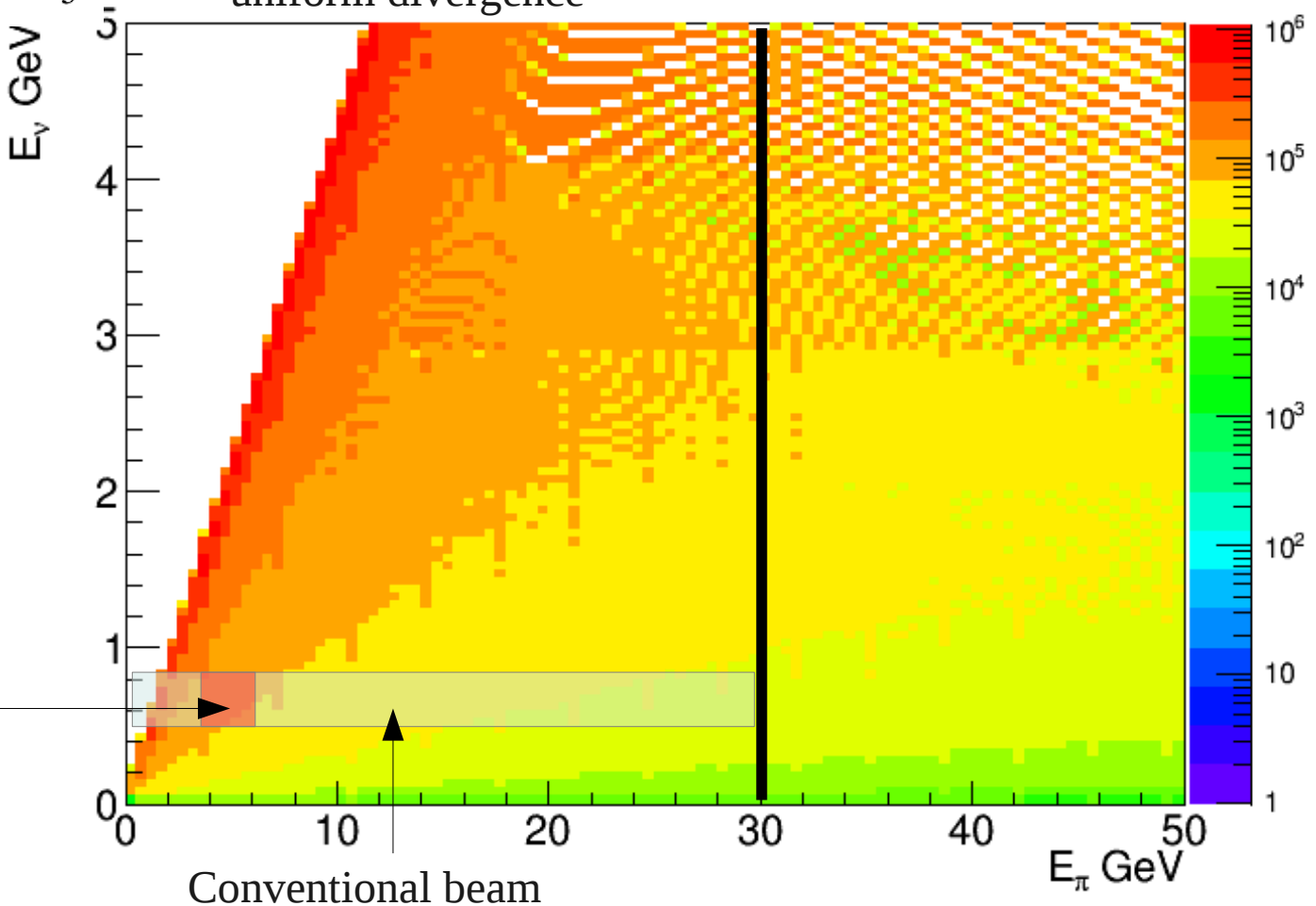


Factor 10 deficiency in flux in energy band of interest

Deficit could be attributed to:

- Scraping from the horn though to the end of the decay straight, and/or
- Total loss of higher energy pions which contribute to energy regime of interest

All possible neutrino energies from pion energies – uniform divergence



nuSTORM

Conventional beam

Summary

- Fluxes from muon and pion decay are established for proposed detector locations
- Initial work on calculating flux precision, but more to do including full consideration of diagnostics
- Flux at other detector locations (SURF, Kamioka) appear lack scaling compared with conventional neutrino beams